# A Population-based Study of the Prevalence and Associated Factors of Diabetes Mellitus in Southern Taiwan

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**Diabetes mellitus is one of the major health care problems in Taiwan, since the mortality rate has increased from 7.91 per 100 000 in 1980 to 35.1 per 100 000 in 1996. To determine the prevalence of diabetes in southern Taiwan and to investigate possible associated factors, a stratified systematic cluster sampling of 1638 subjects (780 men and 858 women) aged ≥20 years living in Tainan city was investigated with a standard 75-g oral glucose tolerance test. The crude prevalence of diabetes in Tainan was 9.0 % (10.3 % men and 7.9 % women) and the age-adjusted prevalence was 9.2 % (10.4 % men and 8.1 % women). The crude prevalence of IGT was 14.0 % (13.8 % men and 14.1 % women), and the age-adjusted prevalence was 15.5 % (15.0 % men and 15.9 % women). The prevalence of diabetes by using the revised new diagnostic criteria was 7.5%. The prevalence of diabetes and IGT increased significantly with age for both genders, although the rises in prevalence of IGT in women was less consistent. Diabetic and IGT subjects were older and had higher levels of BMI, triglyceride, systolic and diastolic blood pressure, and higher prevalence of obesity, hypertension, and dyslipidemia but indulged in less physical activity than non-diabetic subjects. The significant factors associated with the newly diagnosed diabetes were age, family history of DM, BMI, systolic blood pressure, physical activity, and serum triglyceride levels. © 1998 John Wiley & Sons, Ltd.**

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## Introduction

Diabetes mellitus (DM) in adults is a global health problem. Although its prevalence varies widely between different populations from low (<3 %), moderate (3–10 %), high (11–20 %) to extremely high (>20 %), the rate has generally increased worldwide.[1–4] To ascertain the prevalence of diabetes through population-based studies becomes an important issue for planning of health services, analysing associated factors, evaluating medical trends, and estimating community impact. In Taiwan, the mortality rate of diabetes mellitus has almost doubled over the past 10 years and its ranking in the leading causes of death has increased: twelfth in 1982, eighth in 1983, seventh in 1984 and fifth since 1987.[5] It has become one of the major health problems of the country. The prevalence of diabetes in northern Taiwan was previously established between 1985 to 1991 and the rates were between 2.6 % and 5.8 %.[6–8] However, none of these studies subjected the total study population to the standard oral glucose tolerance test (OGTT). Most of them used overnight fasting plasma glucose or capillary whole blood glucose as a first step screening, then the subjects whose fasting glucose level was between 5.6 and 7.8 mmol $l^{-1}$ received a 75 g OGTT. Therefore, the prevalence of diabetes may be underestimated, since some subjects with overnight fasting plasma glucose <5.6 mmol $l^{-1}$ could have had OGTT 2-h glucose level ≥11.1 mmol $l^{-1}$.[8] The prevalence of impaired glucose tolerance (IGT) also cannot be estimated by the two-step method. For better comparison of prevalence data in different populations, the standardized criteria of World Health Organization (WHO)[9] should be applied to determine the exact prevalence of diabetes and IGT in Taiwan. The comparison of the prevalence of diabetes between the current WHO criteria and the revised new criteria of the Expert Committee of the American Diabetes Association[10] is also potentially important. Moreover, prevention of DM by identification and avoidance of its risk factors, such as obesity and sedentary lifestyle are becoming important issues in public health.[11,12] A community-based epidemiological study was conducted by using OGTT from January to December in 1996 to determine the prevalence of diabetes and IGT in the people who were aged ≥20 years living in Tainan

Abbreviations: BMI body mass index, CHO cholesterol, BP diastolic blood pressure, FPG fasting plasma glucose, IFG impaired fasting glucose, IGT impaired glucose tolerance, SBP systolic blood pressure, TG triglyceride, WHR waist-hip ratio

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city, and to investigate possible risk factors associated with DM.

## Patients and Methods

The study was performed in Tainan city, the oldest city in southern Taiwan, with a population of 700 000. The sampling scheme was a three-stage process that generated a stratified systemic cluster sample of households throughout the city. First, areas of the city were grouped into seven strata according to the administrative districts. One area (Li) was randomly selected from each stratum. At the second stage, every fifth household within each of the seven selected areas were identified systematically. In the third stage, the selected households were informed about the survey by letter and telephone from the medical centre to ask the consent for participation and to arrange the schedule of examination. All of the subjects whose age was 20 years or more according to the government population register in 1995 were included in the study.

With the help of specially trained assistants, all subjects were interviewed according to a structured questionnaire. The questionnaire included demographic information, past medical history of diabetes and hypertension, medication history, current smoking habit, current drinking habit, physical activity over the past year, and family history of DM and hypertension. Height and weight were measured in light clothing without shoes. Body mass index (BMI) was calculated as weight × height$^{-2}$ (kg m$^{-2}$). Obesity was defined as a BMI ≥27 for men and ≥25 for women, according to the National Diabetes Data Group criteria.[13] Waist (midway between the lower rib margin and the iliac crest) and hip (widest circumference over the great trochanters) circumferences were measured with subjects standing relaxed without clothing and with a standard dressmaker's tape after normal expiration[14] and the waist-to-hip circumference ratio (WHR) was calculated as an index of central obesity.

All subjects who did not have a medical history of diabetes received a 75-g OGTT after a 10-h overnight fast, a normal diet for 3 days before the test, and abstention from smoking for >24 h. None of the women were pregnant when tested. Fasting venous blood was sampled for assessment of serum lipids, lipoproteins and plasma glucose levels and kept frozen (–80°C) until analysis. Plasma glucose was analysed by the standard glucose-oxidase method (Synchron CX3, Beckman). The coefficients of variation (CV) for intra-assay was 1.2 % and for inter-assay was 1.5 % at the upper end of the reference range. The presence of DM was assessed using questions about the person's previously diagnosed diabetes and using a 2-h OGTT. The participants were designated to have previously diagnosed diabetes if in either of the above questionnaires he/she reported having diabetes treated with diet, oral hypoglycaemic agents or insulin. They were tested only for fasting plasma glucose levels. All the subjects who underwent a 2-h OGTT were classified according to the current WHO criteria[9] for DM and IGT, and revised new criteria[10] for DM and IFG (impaired fasting glucose). The subjects were determined to have newly diagnosed diabetes if they were not previously diagnosed diabetes, but the 2-h OGTT demonstrated a diabetic level.

Fasting serum total cholesterol and triglyceride were measured enzymatically using automated methods.[15,16] Intra-assay coefficients of variation (CVs) for total cholesterol and triglyceride were 1.8 % and 1.2 %, respectively; and the inter-assay CVs were 3.5 % and 2.5 %, respectively. Hypercholesterolaemia was defined if serum cholesterol level was ≥5.18 mmol l$^{-1}$,[17] and hypertriglyceridaemia was defined if serum triglyceride level was ≥2.26 mmol l$^{-1}$.

Two readings of systolic and diastolic blood pressure were measured in the sitting position with a DINAMAP vital sign monitor (Model 1846SX, Critikon Inc., Irvine, CA)[18] after a 15-min rest period while subjects awaited the second venepuncture for OGTT. Hypertension was defined according to the WHO criteria:[19] a mean blood pressure ≥160 mmHg or diastolic blood pressure ≥95 mmHg, or a history of hypertension and currently receiving treatment.

Total physical activity assessment was calculated in MET-hours per week over all activities for the past year. One MET (metabolic equivalent) represents the energy expended at rest for an individual, expressed in kcal × kg$^{-1}$ (body wt) × h$^{-1}$. First, the average number of hours per week spent for each activity was calculated, including leisure activity, occupational activity, and walking for exercise. Then, hours per week of each activity was multiplied by an estimate of the metabolic cost of that activity, expressed as MET, and the MET-hours per week for each activity was summed over all activities.[20–22]

### *Statistical Methods*

Data storage and retrieval were performed with DBASE III PLUS software. Data analysis was conducted using the Statistical Package for the Social Sciences for Windows (SPSSWIN) statistical software. Truncated age-adjusted prevalence rates were performed by a direct method[23] based on the standard world population of Segi.[24] Since triglyceride levels and physical activity were clearly highly skewed, they were presented and analysed by using log transformation. Due to a large difference in mean age among different diabetic groups, age was adjusted in the comparisons. The ANOVA test and $\chi 2$ test were used to test the differences of variables among IGT, newly diagnosed, previously diagnosed, and non-diabetic subjects. For the possible risk factor analysis, multiple logistic regression was used to test for differences between newly diagnosed diabetes and non-diabetes. The level of significance was set at 0.05.

## Results

A total of 2416 subjects were eligible for inclusion, 1170 (48.4 %) men and 1246 (51.6 %) women. Of the 2416 eligible people, 1638 (67.8 %) participated in the study, 780 (47.6 %) men and 858 (52.4 %) women. The non-responders were slightly younger in age and consisted of more males compared with the responders, but the differences were not statistically significant (data not shown).

Table 1 shows the prevalence of diabetes and IGT by age and sex. The overall crude prevalence of diabetes in subjects ≥20 years of age was 9.0 % (4.8 % previously diagnosed and 4.2 % newly diagnosed). It was higher in men (10.3 %) than in women (7.9 %), but there was no significant difference. Both genders had a higher prevalence of previously diagnosed diabetes (5.4 % men and 4.4 % women) compared to newly diagnosed diabetes (4.9 % men and 3.5 % women). Based on the standard world population of Segi, the age-adjusted prevalences of diabetes were 9.2 % for total (men 10.4 %, women 8.1 %), 4.8 % for previously diagnosed, and 4.4 % for newly diagnosed diabetes. The prevalence of diabetes increased with age for both genders. In the age groups of 20–29 years, and 30–39 years, only newly diagnosed diabetes was found for both genders. In the age groups of 40–49 years, the number of newly diagnosed diabetic subjects was more than the previously diagnosed diabetic subjects, but in the age groups of 50 years and over, the prevalence of previously diagnosed subjects was greater than the newly diagnosed subjects. The overall crude prevalence of IGT was 14.0 %. It was higher in women (14.1 %) than in men (13.8 %), but there was no significant difference. The prevalence of IGT increased with age for men, but was less consistent for women. The age-adjusted prevalences of IGT were 15.5 % for total (men 15.0 %, women 15.9 %).

Table 2 shows the comparison of prevalence of diabetes and IGT between the current WHO criteria and the revised new criteria. Based on a fasting plasma glucose (FPG) ≥7 mmol $l^{-1}$ (126 mg $dl^{-1}$), prevalence of newly diagnosed diabetes (2.6 %) was lower than that was diagnosed from the use of the OGTT (4.2 %). The prevalence of IFG was 3.9 %, which was much lower than the prevalence of IGT (14 %).

Table 3 shows the clinical characteristics of the non-diabetic, IGT, newly diagnosed, and previously diagnosed diabetic subjects. The total diabetic and IGT subjects had a higher mean age, body mass index (BMI), total triglyceride (TG), systolic blood pressure (SBP), diastolic blood pressure (DBP), fasting plasma glucose (FPG), 2-h post-load plasma glucose, but lower total physical activity levels than non-diabetic subjects. Only IGT subjects had higher serum cholesterol (CHO) levels than non-diabetic subjects. There was no significant difference in waist-to-hip ratio (WHR) between non-diabetic and diabetic or IGT groups. The diabetic and IGT subjects also had a higher prevalence of obesity, hypertension, hypercholesterolaemia, and hypertriglyceridaemia than non-diabetic subjects. The prevalence of family history of DM in the diabetic groups was higher than non-diabetic subjects. There was no significant difference in the prevalence of smoking and drinking history between any two groups. The IGT subjects had a lower mean WHR, FPG, 2-h post-load plasma glucose, but had higher total physical activity levels than total diabetic subjects. The IGT subjects had a lower prevalence of obesity, and hypertension, but did not have a different prevalence of hypercholesterolaemia and hypertriglyceridaemia. The newly diagnosed and previously diagnosed diabetic subjects had a higher mean BMI, TG, SBP, FPG, and 2-h post-load plasma glucose levels, and had a lower mean physical activity level than non-diabetic subjects, but showed no significant difference in WHR and CHO. Subjects with newly diagnosed and previously diagnosed diabetes had a higher prevalence of obesity, hypertension, hypercholesterolaemia, and hypertriglyceridaemia than non-diabetic subjects. Only subjects with previously diagnosed diabetes had a higher prevalence of family history of DM than non-diabetic subjects. The previously diagnosed diabetic subjects had significantly higher FPG, but had lower SBP and DBP than the newly diagnosed diabetic subjects. There were no significant differences in age, BMI, WHR, CHO, TG, and total physical activity between previously and newly diabetic subjects.

Table 4 shows odds ratios and 95 % confidence intervals for independent variables with newly diagnosed diabetes in the multiple logistic regression model. The best logistic regression model was fitted with a stepwise-forward strategy. The independent variables were age, sex, family history of DM, BMI, SBP, DBP, physical activity, TG, CHO, smoking status, drinking status, and WHR. According to the final model, the significant factors associated with newly diagnosed diabetes were age, family history of DM, BMI, SBP, physical activity, and TG, but sex, DBP, CHO, smoking status, drinking status, and WHR were not significantly correlated with newly diagnosed diabetes.

## Discussion

The present study is the first community-based epidemiological investigation of the prevalence of diabetes by using a standard OGTT for all subjects not being treated for diabetes in Taiwan. It avoids the weakness of underestimation of prevalence of diabetes by using OGTT only in subjects with fasting plasma glucose larger than 5.6 mmol $l^{-1}$, since subjects with fasting plasma glucose less than 5.6 mmol $l^{-1}$ could have had 2-h glucose levels equal to or higher than 11.1 mmol $l^{-1}$ if they had been tested.[25] The overall crude prevalence of diabetes in this study was 9.0 % and the age-specific standardized prevalence was 9.2 %. In a comparison of the diabetes prevalence studies in northern Taiwan (see Table 5), the prevalence of our study is higher than that in the Taipei city study,[6] the Kin-Hu study,[8] and the Ann-Lo study.[7]



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Table 1. Age and sex-specific prevalence of impaired glucose tolerance, newly diagnosed and previously diagnosed diabetes mellitus in Tainan, Taiwan

| Age groups | Number | Total | | | | Men | | | | Women | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | IGT PR *n* (%) | DM PR *n* (%) | Previous cases *n* (%) | New cases *n* (%) | IGT PR *n* (%) | DM PR *n* (%) | Previous cases *n* (%) | New cases *n* (%) | IGT PR *n* (%) | DM PR *n* (%) | Previous cases *n* (%) | New cases *n* (%) |
| 20–29 | 341 | 14 (4.1) | 4 (1.2) | 0 (0.0) | 4 (1.2) | 7 (4.4) | 2 (1.3) | 0 (0.0) | 2 (1.3) | 7 (3.8) | 2 (1.1) | 0 (0.0) | 2 (1.1) |
| 30–39 | 358 | 27 (7.5) | 7 (2.0) | 0 (0.0) | 7 (2.0) | 12 (7.1) | 3 (1.8) | 0 (0.0) | 3 (1.8) | 15 (7.9) | 4 (2.1) | 0 (0.0) | 4 (2.1) |
| 40–49 | 397 | 79 (19.9) | 26 (6.5) | 7 (1.8) | 19 (4.8) | 28 (15.8) | 14 (7.9) | 4 (2.3) | 10 (5.6) | 51 (23.2) | 12 (5.5) | 3 (1.4) | 9 (4.1) |
| 50–59 | 244 | 43 (17.6) | 33 (13.5) | 23 (9.4) | 10 (4.1) | 22 (20.0) | 17 (15.5) | 11 (10.0) | 6 (5.5) | 21 (15.7) | 16 (11.9) | 12 (9.0) | 4 (3.0) |
| 60–69 | 194 | 44 (22.7) | 50 (25.8) | 34 (17.5) | 16 (8.2) | 24 (23.3) | 29 (28.2) | 17 (16.5) | 12 (11.7) | 20 (22.0) | 21 (23.1) | 17 (18.7) | 4 (4.4) |
| ≥70 | 104 | 22 (21.2) | 28 (26.9) | 16 (15.4) | 12 (11.5) | 15 (23.8) | 15 (23.8) | 10 (15.9) | 5 (7.9) | 7 (17.1) | 13 (31.7) | 6 (14.6) | 7 (17.1) |
| Total | 1638 | 229 (14.0) | 148 (9.0) | 80 (4.9) | 68 (4.2) | 108 (13.8) | 80 (10.3) | 42 (5.4) | 38 (4.9) | 121 (14.1) | 68 (7.9) | 38 (4.4) | 30 (3.5) |
| Adjusted[a] | | 15.5 | 9.2 | 4.8 | 4.4 | 15.0 | 10.4 | 5.2 | 5.2 | 15.9 | 8.1 | 4.5 | 3.6 |

PR, prevalence rate.
[a]Age-adjusted rate by using of standard world population of Segi.

Table 2. Comparison of prevalences of diabetes mellitus and impaired glucose tolerance between the current WHO criteria and the proposed new diagnostic criteria in Tainan in individuals ≥20 years old

| | Prevalence (%) of diabetes and IGT by glucose criteria without a medical history of diabetes | Total diabetes prevalence (%) |
|---|---|---|
| Medical history of diabetes | – | 4.9 |
| WHO criteria for IGT | 14 | – |
| FPG ≥6.1 and FPG <7.0 mmol $l^{-1}$ (IFG) | 3.9 | – |
| WHO criteria for diabetes | 4.2 | 9.0 |
| FPG ≥7.0 mmol $l^{-1}$ | 2.6 | 7.5 |

IGT, impaired glucose tolerance; FPG, fasting plasma glucose; IFG, impaired fasting glucose.

The prevalence of diabetes in the Tainan study is the highest rate that has been reported. Since the age of the present study population was younger than the above three Taiwanese studies, and the urbanization of the present study was lower than in Taipei study, similar to the Ann-Lo study and slightly higher than the Kin-Hu study, we can be sure that an increase in the prevalence of diabetes has been identified. The increase may be related to an increasingly westernized life pattern during the past decades in Tainan. In a comparison of the diabetes prevalence studies in adult Chinese out of Taiwan (see Table 5), the rate was higher than that in the Da Qing, China study,[27] the Singapore study,[4] and the Hong Kong study,[26] but lower than that of the Mauritius study.[28] In a comparison of the prevalence rate among Asian populations (see Table 5), the rate was higher than that in the Vietnamese study,[29] the Korean study,[3] close to that of the Japanese study,[2] but lower than that in the Fiji Asian Indians study.[30] This moderate prevalence of diabetes (3–10 %)[1] may be attributed to the westernized life pattern of population in the process of industrialization (environmental factor), genetic factor, and interaction of both factors.

In the present study, the prevalence of diabetes was higher among men than among women, which was the same as the results in the Hong Kong study (men 5.1 %, women 3.6 %), in the Bangladesh study (men 3.52 %, women 1.13 %), and in the Korean study (men 10.6 %, women 7.9 %). The prevalence rate of newly diagnosed diabetes was close to that of previously diagnosed diabetes, which has been shown in many studies.[31–33] This indicates that diabetes may be twice as prevalent in Tainan city as rates found in medical history surveys. Our study found that women had a lower prevalence of newly diagnosed diabetes than men. It may be attributed to a higher utilization of medical service in women, so diabetes was easily diagnosed during screening programmes. This can be seen from the higher participation rate in women in this study and other studies.[2,8] In the age groups from 20–29 years to 30–39 years, only newly diagnosed diabetes was found. Whether to do diabetes screening in younger age groups especially in the high risk subjects who have a family history of DM, obesity, hypertension, physical inactivity, and hypertriglyceridaemia, should be further investigated since the newly diagnosed diabetic subjects were commonly asymptomatic. The higher prevalence of diabetes in older age groups identified in this study was similar to the findings of other studies.[31,34]

The crude prevalence of IGT was 14.0 %, and the age-specific standardized prevalence was 15.5 %. Since the studies in Taiwan previously did not use standardized OGTT, prevalences of IGT in those studies could not be determined. In a comparison of the IGT prevalence studies in adult Chinese outside of Taiwan (see Table 5), the rate was higher than that in the Da Qing, China study,[27] the Singapore study,[4] and the Hong Kong study,[26] but close to that of the Mauritius study.[28] Comparison of the prevalence rate among Asian populations (see Table 5), showed the rate was higher than that in the Vietnamese study,[29] the Korean study,[3] and the Fiji Asian Indians study,[30] but close to that of the Japanese study.[2] Studies in different Chinese populations who have similar genetic characteristics have shown substantial variation in the prevalence of IGT. This result indicates that environmental factors may play an important role, since the levels of westernization were very different among the Chinese in these areas.

The prevalence of IGT was higher among women than men, which was the same as the Mauritius study,[28] and the Fiji Asian Indians study.[30] However, the difference in prevalence IGT between men and women varies widely across populations.[1] The prevalence of IGT increased with age, which was the same as the US study.[31]

The prevalence of diabetes without a medical history of diabetes (newly diagnosed diabetes) by using the revised new criteria was 2.6 %, which was lower than that using WHO criteria (4.2 %). The same result was also found in the US NHANES III study.[10] From univariate analyses, after adjusting for age, the study showed that the newly and previously diagnosed diabetic subjects had higher mean BMI, TG, SBP, DBP, FPG, 2-h post-load plasma glucose than non-diabetic subjects, which was also demonstrated before.[35] This means that the newly and previously diagnosed diabetic subjects had the same unfavourable risk factors for coronary heart disease, so it is worthwhile for us to consider the problems found in the newly diagnosed diabetic subjects.



 

Table 3. Comparisons of clinical characteristics of non-diabetic, IGT, newly diagnosed diabetic and previously diagnosed diabetic subjects

| | Non-diabetic | IGT | Diabetes mellitus | | |
|---|---|---|---|---|---|
| | | | New cases | Previous cases | Total cases |
| Number | 1261 | 229 | 68 | 80 | 148 |
| Age (yr) | 40.7 ± 14.4 | 50.9 ± 13.8[c] | 54.3 ± 15.4[c] | 61.3 ± 8.5[c] | 58.1 ± 12.6[c] |
| BMI (kg $m^{-2}$) | 23.2 ± 3.4 | 25.1 ± 3.9[c] | 25.6 ± 3.5[b] | 25.8 ± 3.3[b] | 25.7 ± 3.4[c] |
| WHR | 0.845 ± 0.270 | 0.890 ± 0.085 | 0.920 ± 0.078 | 0.946 ± 0.077[e] | 0.934 ± 0.078[e] |
| Cholesterol (mmol $l^{-1}$) | 4.9 ± 1.1 | 5.3 ± 1.0[b] | 5.4 ± 1.4 | 5.3 ± 1.4 | 5.4 ± 1.4 |
| Triglyceride (mmol $l^{-1}$)[j] | 0.040 ± 0.235 | 0.177 ± 0.224[c] | 0.249 ± 0.330[c] | 0.232 ± 0.255[c] | 0.246 ± 0.291[c] |
| Systolic blood pressure (mmHg) | 115.0 ± 18.5 | 127.8 ± 22.1[c] | 137.0 ± 28.5[c,d] | 133.9 ± 21.6[c,h] | 135.3 ± 25.0[c] |
| Diastolic blood pressure (mmHg) | 69.5 ± 10.2 | 74.7 ± 11.7[c] | 79.5 ± 11.7[c,d] | 77.1 ± 10.1[g] | 78.2 ± 10.9[c] |
| Fasting plasma glucose (mmol $l^{-1}$) | 5.0 ± 0.5 | 5.4 ± 0.6[c] | 7.9 ± 3.2[c,f] | 9.5 ± 3.7[c,f,h] | 8.8 ± 3.6[c,f] |
| 2-h plasma glucose (mmol $l^{-1}$) | 5.5 ± 1.2 | 8.9 ± 0.9[c] | 14.7 ± 4.4[c,f] | 15.4 ± 7.7[c,f] | 15.0 ± 6.4[c,f] |
| Physical activity (MET-hr $week^{-1}$)[j] | 1.65 ± 0.47 | 1.59 ± 0.48[a] | 1.48 ± 0.42[b] | 1.37 ± 0.55[c,d] | 1.42 ± 0.49[c,d] |
| Sex | | | | | |
| Male | 592 (46.9) | 108 (47.2) | 38 (55.9) | 42 (52.5) | 80 (54.1) |
| Female | 669 (53.1) | 121 (52.8) | 30 (44.1) | 38 (47.5) | 68 (45.9) |
| Smoking | | | | | |
| No | 995 (78.9) | 185 (80.8) | 51 (75.0) | 63 (78.8) | 114 (77.0) |
| Yes | 266 (21.1) | 44 (19.2) | 17 (25.0) | 17 (21.3) | 34 (23.0) |
| Drinking | | | | | |
| No | 1106 (87.7) | 193 (84.3) | 56 (82.4) | 71 (88.8) | 127 (85.8) |
| Yes | 155 (12.3) | 36 (15.7) | 12 (17.6) | 9 (11.3) | 21 (14.2) |
| Family history of DM | | | | | |
| No | 1036 (82.2) | 182 (79.5) | 52 (76.5) | 58 (72.5)[a] | 110 (74.3)[a] |
| Yes | 225 (17.8) | 47 (20.5) | 16 (23.5) | 22 (27.5) | 38 (25.7) |
| Obesity | | | | | |
| BMI <27 for M; <25 for F | 1015 (80.6) | 154 (67.2)[c] | 40 (59.7)[c] | 43 (53.8)[c,d] | 83 (56.5)[c,d] |
| BMI ≥27 for M; ≥25 for F | 244 (19.4) | 75 (32.8) | 27 (40.3) | 37 (46.3) | 64 (43.5) |
| Hypertension | | | | | |
| <160/95 mmHg | 1154 (91.5) | 176 (76.9)[c] | 43 (63.2)[c,d] | 55 (68.8)[c] | 98 (66.2)[c,d] |
| ≥160/95 mmHg | 107 (8.5) | 53 (23.1) | 25 (36.8) | 25 (31.3) | 50 (33.8) |
| Hypercholesterolaemia | | | | | |
| <5.18 mmol $l^{-1}$ | 803 (63.7) | 111 (48.5)[c] | 32 (47.1)[a] | 41 (51.3)[a] | 73 (49.3)[c] |
| ≥5.18 mmol $l^{-1}$ | 458 (36.3) | 118 (51.5) | 36 (52.9) | 39 (48.8) | 75 (50.7) |
| Hypertriglyceridaemia | | | | | |
| <2.26 mmol $l^{-1}$ | 1139 (90.3) | 179 (78.2)[c] | 45 (66.2)[c,d] | 59 (73.8)[c] | 104 (70.3)[c] |
| ≥2.26 mmol $l^{-1}$ | 122 (9.7) | 50 (21.8) | 23 (33.8) | 21 (26.3) | 44 (29.7) |

Non-diabetics vs IGT, newly diagnosed, previously diagnosed, and total diabetics: [a]$p < 0.05$, [b]$p < 0.01$, [c]$p < 0.001$.
IGT vs newly diagnosed, previously diagnosed, and total diabetics: [d]$p < 0.05$, [e]$p < 0.01$, [f]$p < 0.001$.
Newly diagnosed vs previously diagnosed: [g]$p < 0.05$, [h]$p < 0.01$, [i]$p < 0.001$.
[j]With log transformation; ANOVA test (age adjusted) or $\chi^2$ test.
Data are presented either with % in brackets or as mean ± SD.

In several studies,[11,35] previously diagnosed diabetic subjects had significantly higher FPG than newly diagnosed diabetic subjects, as was also demonstrated by our study. This indicates that previously diagnosed diabetic subjects did not have their blood glucose under good control.[11,35] The result that newly diagnosed diabetic subjects had significantly higher SBP than previously diagnosed diabetic subjects also was found in the Pu-Li study.[11] This result may be explained by having good blood pressure control in previously diagnosed diabetic subjects during treatment of their diabetes.

Subjects with IGT had the intermediate levels of risk factors for coronary heart disease, such as age, BMI, TG, SBP, DBP, FPG, 2-h plasma glucose, and physical activity, which has also been reported in a US study.[36] This indicates that IGT has the similar risk factors for coronary heart disease and may be seen to be an intermediate stage in diabetic development.[36]

From the results of multiple logistic regression, the significant risk factors associated with newly diagnosed diabetes were age, family history of DM, BMI, SBP, physical activity and TG. Age as an independent predictor of diabetes has been reported in many studies.[37,38] Family history of DM as a significant predictor for diabetes has also been demonstrated in several studies.[3,11,39–41] The relationship between physical activity and diabetes is controversial depending on the questionnaire used.[21] In our study, the structured questionnaire[20] accurately assessed the activity patterns in work, walking and leisure time; the results showed that higher physical activity can reduce the risk of diabetes. Many prospective studies have also shown that increased physical activity is associated with a reduced risk of diabetes.[42–44] The mechanism may be related to increasing insulin sensitivity in skeletal muscle caused by physical activity.[45]

In addition, BMI,[39,40,46,47] SBP,[7,8,47–50] and TG[47,51–53] have also been associated with prevalence of diabetes from many studies. It could be explained by insulin resistance and hyperinsulinemia suggested by Reaven in his Banting lecture in 1988[54] and from many other studies.[55,56] The mechanism is that obese subjects are resistant to insulin-stimulated glucose uptake, which in turn leads to an increase in insulin concentration, enhanced hepatic very-low-density lipoprotein triglyceride secretion and hypertriglyceridaemia, and leads to a reduction of sodium excretion, enhanced sympathetic nervous system activity, and hypertension.[57]

Table 4. Multiple logistic regression analysis on the newly diagnosed diabetes mellitus in Tainan, Taiwan

| Variables | Odds ratio | 95% C.I. |
|---|---|---|
| Age (yr) | 1.04 | 1.02–1.07 |
| Sex (men = 0; women = 1) | 0.91 | 0.50–1.66 |
| Family history of DM (no = 0; yes = 1) | 2.07 | 1.04–4.08 |
| BMI (kg $m^{-2}$) | 1.11 | 1.02–1.21 |
| SBP (mmHg) | 1.02 | 1.01–1.04 |
| Physical activity (MET-hr $wk^{-1}$)[a] | 0.33 | 0.18–0.62 |
| Triglyceride (mmol $l^{-1}$)[a] | 7.44 | 2.33–23.76 |

[a]Log transformation; dependent variable is newly diagnosed diabetes vs non-diabetes. Independent variables are age, sex, family history of DM, body mass index (BMI), systolic blood pressure (SBP), diastolic blood pressure (DBP), physical activity, triglyceride, cholesterol, smoking, drinking, and waist-to-hip ratio (WHR).

Table 5. Prevalence of diabetes and IGT in Chinese and Asian populations

| Country/Population | Age range (yr) | Sample size | Study year | DM Crude rate | DM Adjusted rate | IGT Crude rate | IGT Adjusted rate | Reference |
|---|---|---|---|---|---|---|---|---|
| Chinese (in Taiwan) | | | | | | | | |
| Tainan | ≥20 | 1 638 | 1996 | 9.0 | 9.2 | 14.0 | 15.5 | [d] |
| Taipei[a] | ≥40 | 11 478 | 1985 | 6.2 | 5.8 | – | – | 6 |
| Ann-Lo, Keelung[b] | ≥40 | 2 448 | 1988 | 8.0 | 8.0 | – | – | 7 |
| Kin-Hu, Kinmen[c] | ≥30 | 3 236 | 1991 | 6.5 | 4.9 | – | – | 8 |
| Chinese (outside of Taiwan) | | | | | | | | |
| Da Qing, China | 25–74 | 110 660 | 1986 | 0.77 | 1.6 | 0.6 | 0.9 | 27 |
| Singapore | ≥18 | 1 417 | 1985 | 4.0 | M4.6,F4.9 | 0.6 | M0.8,F0.3 | 4 |
| Hong Kong | 18–64 | 1 513 | 1991 | 4.5 | 7.7 | 7.3 | M11.2,F8.8 | 26 |
| Mauritius | 25–74 | 412 | 1987 | 11.7 | 11.5 | 16.5 | M16.5,F21.7 | 28 |
| Asian | | | | | | | | |
| Vietnam | ≥15 | 4 912 | 1990 | 1.2 | 1.4 | 1.6 | 1.7 | 29 |
| South Korea | ≥30 | 2 497 | 1991 | 9.1 | 7.2 | 11.8 | 8.9 | 3 |
| Japan | ≥45 | 916 | 1990 | 11.9 | 10.4 | 16.6 | 15.3 | 2 |
| Fiji, Indian (urban) | ≥20 | 846 | 1980 | 13.1 | M12.9,F11.0 | 10.3 | M8.3,F11.8 | 30 |

[a]Capillary blood glucose either after overnight fasting or 2-h postprandial by use of glucometer.
[b]2-h postprandial blood glucose (Glucocheck SC B-2) or urinary glucose and adjusted with the population in Taiwan.
[c]OGTT for subject with fasting plasma glucose levels between 5.6 and 7.8 mmol $l^{-1}$.
[d]Present study: M: male, F: female.

In conclusion, the crude prevalence of diabetes was 9.0 % and 7.5 % by using WHO criteria and revised new criteria, respectively, and the age-adjusted prevalence of diabetes and IGT were 9.2 % and 15.5 %. The possible risk factors of newly diagnosed diabetes were age, family history of DM, BMI, SBP, triglyceride, and physical activity. In Taiwan, the mortality rates of diabetes were greatly increased over the past 10 years. Reduction of the modifiable risk factors such as BMI, hypertension, and hypertriglyceridaemia, and increase of physical activity through public health programmmes may help to reduce the risk of diabetes.

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## References

1. King H, Rewers M, WHO Ad Hoc Diabetes Reporting Group. Global estimates for prevalence of diabetes mellitus and impaired glucose tolerance in adults. *Diabetes Care* 1993; **16**: 157–177.
2. Sekikawa A, Tominaga M, Takahashi K, Eguchi H, Igarashi M, Ohnuma H, *et al*. Prevalence of diabetes and impaired glucose tolerance in Funagata area, Japan. *Diabetes Care* 1993; **16**: 570–574.
3. Park Y, Lee H, Koh CS, Min H, Yoo K, Kim Y, Shin Y. Prevalence of diabetes and IGT in Yonchon County, South Korea. *Diabetes Care* 1995; **18**: 545–548.
4. Thai AC, Yeo PPB, Lun KC, Hughes K, Ng WY, Lui KF, Cheah JS. Diabetes mellitus and its chronic complications in Singapore: an increasing healthcare problem. *Annals Academy of Med*, Singapore 1990; **19**: 517–523.
5. Department of Health. *Health and Vital Statistics. I. General Health Statistics*, Taipei, Republic of China: Department of Health, Executive Yuan, 1996.
6. Tai TY, Yang CL, Chang CJ, Chang SM, Chen YH, Lin BJ, *et al*. Epidemiology of diabetes mellitus among adults in Taiwan, *R.O.C. J of the Medical Association of Thailand* 1987; **70** (suppl 2): 42–48.
7. Lin JD, Shieh WB, Huang MJ, Huang HS. Diabetes mellitus and hypertension based on the family history and 2-h postprandial blood sugar in the Ann-Lo district (Northern Taiwan). *Diabetes Res Clin Pract* 1993; **20**: 75–85.
8. Chou P, Liao MJ, Kuo HS, Hsiao KJ, Tsai ST. A population survey on the prevalence of diabetes in Kin-Hu, Kinmen. *Diabetes Care* 1994; **17**: 1055–1058.
9. WHO Study Group on Diabetes Mellitus. *Diabetes Mellitus*. WHO Technical Report Series 727. Geneva: WHO, 1985; 9–12.
10. The Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. Report of the expert committee on the diagnosis and classification of diabetes mellitus. *Diabetes Care* 1997; **20**: 1183–1197.
11. Chou P, Chen HH, Hsiao KJ. Community-based epidemiological study on diabetes in Pu-Li, Taiwan. *Diabetes Care* 1992; **15**: 81–89.
12. WHO Study Group on Diabetes Mellitus. *Diabetes Mellitus*. WHO Technical Report Series 727. Geneva: WHO, 1985: 92.
13. National Diabetes Data Group. Classification and diagnosis of diabetes mellitus and other categories of glucose intolerance. *Diabetes* 1979; **28**: 1039–1057.
14. Seidell JC, Cigolini M, Charzewska J, Ellisinger BM, Biase GD, Bjorntorp P, *et al*. Androgenicity in relation to body fat distribution and metabolism in 38-year-old women. The European fat distribution study. *J Clin Epidemiol* 1990; **43**: 21–34.
15. Nobbs BT, Smith JM, Wallar AW. Enzymatic determination of plasma cholesterol on discrete automatic analyzers. *Clin Chem Acta* 1977; **79**: 391–398.
16. Bucolo G, David H. Quantitative determination of serum triglycerides by the use of enzymes. *Clin Chem* 1973; **19**: 476–482.
17. The Expert Panel. Report of the National Cholesterol Education Program: expert panel on detection, evaluation, and treatment of high blood cholesterol in adults. *Arch Intern Med* 1988; **148**: 36–69.
18. Frohlich ED, Grim C, Labarthe DR. Recommendations for human blood pressure determination by sphygmomanometers: report of a task force appointed by the Steering Committee, American Heart Association. *Hypertension* 1988; **11**: 209A–222A.
19. World Health Organization. *Hypertension and Coronary Heart Disease: Classification and Criteria for Epidemiological Study*. WHO Technical Report Series 168. Geneva: WHO, 1959.
20. Kriska AM, Bennett PH. An epidemiological prospective of the relationship between physical activity and NIDDM: from activity assessment to intervention. *Diabetes Metab Rev* 1992; **4**: 355–372.
21. Kriska AM, Knowler WC, LaPorte RE, Drash AL, Wing RR, Blair SN, *et al*. Development of questionnaire to examine relationship of physical activity and diabetes in Pima Indians. *Diabetes Care* 1990; **13**: 401–411.
22. Paffenbarger RS, Blair SN, Lee IM, Hyde RT. Measurement of physical activity to assess health effects in free-living populations. *Med Sci Sports Exerc* 1993; **25**: 60–70.
23. Lilienfield DE, Stolley PD. *Foundations of Epidemiology*, 3rd edn. Oxford: Oxford University Press, 1994; 68–72.
24. Segi M. *Cancer Mortality for Selected Sites in 24 Countries (1950–57)*. Sendai: Tohuku University School of Medicine, 1960.
25. McLarty DG, Swai AB, Kitange HM, Masuki G, Mtinangi BL, Kilima PM, Makene WJ, Chuwa IM, Alberti KG. Prevalence of diabetes and impaired glucose tolerance in rural Tanzania. *Lancet* 1989; **i**: 871–875.
26. Cockram CS, Woo J, Lau E, Chan JC, Chan AY, Lau J, *et al*. The prevalence of diabetes mellitus and impaired glucose tolerance among Hong Kong Chinese adults of working age. *Diabetes Res Clin Pract* 1993; **21**: 67–73.
27. Pan SR, Hu YH, Li GW, Liu PA, Bennett PH, Howard BV. Impaired glucose tolerance and its relationship to ECG-indicated coronary heart disease and risk factors among Chinese-Da Qing IGT and diabetes study. *Diabetes Care* 1993; **16**: 150–156.
28. Dowse GK, Zimmet PZ, Gareeboo H, George K, Alberti MM, Tuomilehto J, *et al*. Abdominal obesity and physical inactivity as risk factors for NIDDM and impaired glucose tolerance in Indian, Creole, and Chinese Mauritians. *Diabetes Care* 1991; **14**: 271–282.
29. Quoc PS, Charles MA, Cuong NH, Lieu LH, Tuan NA, Thomas M, *et al*. Blood glucose distribution and prevalence of diabetes in Hanoi. *Am J Epidemiol* 1994; **139**: 713–722.
30. Zimmet P, Taylor R, Ram P, King H, Sloman G, Raper



 

LR, Hunt D. Prevalence of diabetes and impaired glucose tolerance in the biracial (Melanesian and Indian) population of Fiji: a rural-urban comparison. *Am J Epidemiol* 1983; **118**: 673–688.
31. Harris MI, Hadden WC, Knowler WC, Bennett PH. Prevalence of diabetes and impaired glucose tolerance and plasma glucose levels in U.S. population aged 20–74 yr. *Diabetes* 1987; **36**: 523–534.
32. Fujumoto WY, Leonetti DL, Kinyoun JL, Neweel-Morris L, Shuman WP, Stolov WC, Wahl PW. Prevalence of diabetes mellitus and impaired glucose tolerance among second-generation Japanese-American men. *Diabetes* 1987; **36**: 721–729.
33. French LR, Boen JR, Martinez AM, Bushhouse SA, Sprafka JM, Goetz FC. Population-based study of impaired glucose tolerance and type II diabetes in Wadena, Minnesota. *Diabetes* 1990; **39**: 1131–1137.
34. Zimmet P. Type 2 (non-insulin-dependent) diabetes: an epidemiological overview. *Diabetologia* 1982; **22**: 399–411.
35. Chang CJ, Fu CC, Chen MS, Yang CL, Chen YJ, Chuang LM, *et al*. A comparison of newly and previously diagnosed diabetics in Taiwan. *J Formosan Med Assoc* 1990; **89**: 264–269.
36. Harris MI. Impaired glucose tolerance—prevalence and conversion to NIDDM. *Diabetic Med* 1996; **13**: S9–S11.
37. Lipton RB, Liao Y, Cooper RS, McGee D. Determinants of incident non-insulin-dependent diabetes mellitus among blacks and whites in a national sample: the NHANES I Epidemiologic Follow-up Study. *Am J Epidemiol* 1993; **138**: 826–839.
38. Wilson PW, Anderson KM, Kannel WB. Epidemiology of diabetes mellitus in the elderly: The Framinghan Study. *Am J Med* 1986; **80** (supply 5A): 3–9.
39. Butler WJ, Ostrander LD, Carman WJ, Lamphiear DE. Diabetes mellitus in Tecumseh, Michigan: prevalence, incidence, and associated conditions. *Am J Epidemiol* 1982; **116**: 971–980.
40. Knowler WC, Bennett PH, Hamman RF, Miller M. Diabetes incidence and prevalence in Pima Indians: a 19-fold greater incidence than in Rochester, Minnesota. *Am J Epidemiol* 1978; **108**: 497–505.
41. Zimmet P, Taft P, Guinea A, Guthrie W, Thoma K. The high prevalence of diabetes mellitus on a central Pacific Island. *Diabetologia* 1977; **13**: 113–115.
42. Helmrich SP, Ragland DR, Leung RW, Paffenbarger RS. Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus. *N Engl J Med* 1991; **325**: 147–152.
43. Manson JE, Rimm EB, Stampfer MJ, Colditz GA, Willett WC, Krolewski AS, *et al*. Physical activity and incidence of non-insulin-dependent diabetes mellitus in women. *Lancet* 1991; **338**: 774–778.
44. Manson JE, Nathan DM, Krolewski AS, Stampfer MJ, Willett WC, Hennekens CH. A prospective study of exercise and incidence of diabetes in US male physicians. *J Am Med Assoc* 1992; **268**: 63–67.
45. Devlin JT. Effects of exercise on insulin sensitivity in humans. *Diabetes Care* 1992; **15**: 1690–1693.
46. Keen H, Thomas BJ, Jarrett RJ, Fuller JH. Nutrient intake, adiposity and diabetes. *Br Med J* 1979; **1**: 655–658.
47. Medalie JH, Papier CM, Glodbourt MA, Herman JB. Major factors in the development of diabetes mellitus in 10,000 men. *Arch Intern Med* 1975; **135**: 811–817.
48. Harlan LC, Harlan WR, Land, Goldstein NG. Factors associated with glucose tolerance in adults in United States. *Am J Epidemiol* 1987; **126**: 80–84.
49. Feskens EJM, Kromhout D. Cardiovascular risk factors and the 25-year incidence of diabetes mellitus in middle-aged men: The Zuphen Study. *Am J Epidemiol* 1989; **130**: 1101–1108.
50. Morales PA, Mitchell BD, Valdez RA, Hazuda HP, Stern MP, Haffner SM. Incidence of NIDDM and impaired glucose tolerance in hypertensive subjects: The San Antonio Heart Study. *Diabetes* 1993; **42**: 154–161.
51. Wilson PW, McGee DL, Kannel WB. Obesity, very low density lipoproteins, and glucose intolerance over fourteen years. *Am J Epidemiol* 1981; **114**: 697–704.
52. Barrett-Connor E, Grundy SM, Holdbrook MJ. Plasma lipids and diabetes mellitus in an adult community. *Am J Epidemiol* 1982; **115**: 657–663.
53. Cruz-Vidal M, Costas R Jr, Garcia-Palmieri MR, Sorlie PH, Hertzmark E. Factors related to diabetes mellitus in Puerto Rican men. *Diabetes* 1979; **28**: 300–307.
54. Reaven GM. Banting lecture 1988: Role of insulin resistance in human disease. *Diabetes* 1988; **37**: 1595–1607.
55. DeFronzo RA, Ferrannini E. Insulin resistance: a multifaceted syndrome responsible for NIDDM, obesity, hypertension, dyslipidemia, and atherosclerotic cardiovascular disease. *Diabetes Care* 1991; **14**: 173–194.
56. Reaven GM, Lithell H, Landsberg L. Hypertension and associated metabolic abnormalities: the role of insulin resistance and the sympathoadrenal system. *N Engl J Med* 1996; **334**: 374–381.
57. Flack JM, Sowers JR. Epidemiologic and clinical aspects of insulin resistance and hyperinsulinemia. *Am J Med* 1991; **91**(suppl 1A): 11S–21S.